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Load balancing mechanism for data-centric routing in wireless sensor networks ☆

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ABSTRACT

Routing protocols in wireless sensor networks are became one of the most challenges for these last years. Proposing an efficient and a suitable routing protocol was the aim of many works to route the data with a less consumption of energy and to prolong the network lifetime. This paper investigates a proposition of a new variant of the reference routing protocol *Directed Diffusion*. This variant, that we call DDLB (Directed Diffusion with Load Balancing mechanism), tries to improve the DD algorithm by introducing a load balancing mechanism in order to balance the energy of the sensors and improve the network lifetime. Simulation results, under the Network Simulator 2 (NS2), show that DDLB can improve the performance more than the standard DD protocol in terms of network lifetime and response time. Further, results show that DDLB can efficiently balance the energy load of the sensors.

1. Introduction

The emergence of the wireless and mobile networks opens new opportunities in the telecommunication domains. The wireless communication is considered to be one of the most recognized technologies. It offers open solutions to provide services where the installation of the cable based infrastructure is impossible or mainly difficult.

However, to make this kind of communication attractive, flexible and with fewer infrastructures, a new generation of networks is appeared and, called: Wireless Sensor Networks (WSNs). These sensors contain devices of sensing and wireless communication in only one circuit with a system on chip design and a cost-effectiveness.

Nevertheless, one of the major problems in this network is the energy consumption. The emission and the reception of the packet, at the time of the communication, is a costly process in terms of energy. Thus, routing the data from the sensor that sense the event (the source) to the sink must be efficient by choosing the optimal path in terms of energy of sensors and, eventually the distance from the sink.

Several protocols of different classes were proposed in the literature to deal with the problem of the energy consumption such as: linear routing [1–6], hierarchical routing [7,8], localization based routing [9,4], QoS based routing [10], multi paths routing [1,3,6], negotiation based routing [1,10,5] and flow control based routing [8,3]. The class of linear routing

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(data-centric routing) was studied for the applications based on the request–response mechanism. Then, the sink requests the required data by sending the interest (request of type (attribute, value)) to the concerned sensors which reply by sending the dedicated data.

The protocol Directed Diffusion (DD) [1] was considered a protocol of reference for the data-centric routing applications. In DD, the sink requests the required data by sending the interest to the concerned sensors. During the dissemination process of the interest, gradients (paths of responses between the sources and the sink) are established in order to trace paths being used to collect the sensed events. Thereafter, one of these paths is reinforced to route the data.

In this paper, we propose a new variant of the protocol Directed Diffusion that we call: DDLB (Directed Diffusion with Load Balancing mechanism). In DDLB, we introduce a load balancing mechanism [11] into the Directed Diffusion protocol in order to balance the energy of the sensors and improve the network lifetime. In fact, load balancing is a reliable and a powerful mechanism that has showed success in several domains, mainly the task assignment in distributed server systems. In these systems, one dispatcher assigns incoming tasks (requests of clients) to one of the homogeneous servers of the system. The dispatcher aims to share or balance the load of tasks on the servers by using a load balancing mechanism and improves the performance (optimal use of the server resources, minimum of response time, etc.). So, we specify one sensor from the sensors of the same zone and that can sense the same information to process as a dispatcher. This last dispatches the interests to the sensors in order to balance their energy and dedicates one sensor to route the data to the sink when the path is reinforced. Simulation results, performed under the Network Simulator 2 (NS2), show that DDLB can improve the performance than the standard protocol DD in terms of network lifetime and response time, and can balance the energy load of the sensors.

The remainder of the paper is organized as follows: Section 2 reviews some previous works on load balancing in sensor networks. Section 3 reviews the standard protocol Directed Diffusion. The description and the conception of the new protocol DDLB are the subject of the Section 4. In Section 5, we discuss the simulation results of DDLB and DD and, we conclude the work in Section 6.

2. Related works

Some works were proposed for the load balancing in wireless sensor networks. Dai and Han [12] try to create a balanced tree of sensors. The sensors periodically broadcast their existence and neighboring information. After collecting these information, the sink constructs the graph $G(V,E)$. An algorithm is executed on G to construct a load-balanced tree. We show that the tree takes into account just the existence and the neighboring information without considering the load of the sensors in terms of energy. The authors in [13,14] try to balance the energy of the sensors by considering some information in the routing process. When the authors in [13] consider the location, the power and the load as metrics for the selection of the intermediate sensors which transmit the data between the source and the destination, the authors in [14] take into account the remaining energy of the sensor, the buffer capacity, the transmission delay and the link quality. The papers consider that these information must be exchanged between the sensors in order to take a routing decision. Thus, this makes some additional time and some unnecessary consumed energy which are not considered when improving the routing process and balancing the energy of the sensors. Baek and de Veciana [15], by considering clusters, try to aggregate the data of the sensors before sending them to the sink. The authors did not consider the case when the sensors sense the same data. In this case, the aggregation is not favorable because it adds some delay to the transmission time of the data. The authors in [16] try to improve LEACH by dividing the sensors into two layers of multi hop communication. The bottom layer that involves intra-cluster communication and the top layer that involves inter-cluster communication involving the temporary cluster heads. Recently, some works try to balance the load by conceiving some schemes of organization of the sensors in the network. Liao et al. [17] have proposed a grid-based scheme to balance the load assigned to the sensors. Authors in [18] have proposed a new scheme to partition the nodes into clusters of unequal size to balance the energy load. Further, the authors of [19] have proposed an infrastructure able to self-organize the nodes in the sensor networks by exploiting the local interactions and the topology learning among devices.

Our work is different from all the above in so far it focuses on applying a load balancing mechanisms (mostly used in distributed server systems) to the data-centric sensor networks (when most of the cited works are event-based sensor networks) in order to preserve the energy of the sensors and improve the network lifetime. By creating the zones, the choice of the sensor that routes the data is based on a load balancing mechanism that takes into account the load (in terms of energy) of the sensors.

3. The Directed Diffusion protocol

The class of linear protocols is a class of protocols where all the sensors have the same tasks and collaborate in the sensing process. Due to the large number of sensors in the network, it is mainly impossible to attribute an identifier to each sensor (at the difference with ad hoc networks where each node is designed by an IP address). Thus, a principle of the data-centric routing was introduced. It assumes that the information, produced by the sensors, is of the type (attribute, value). For example, in an agriculture field, these attributes are used to describe the sensed phenomena (temperature, CO_2 rate,...), its